UNMANNED FREIGHT OPERATIONS

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Abstract

The significance of civil applications of unmanned aircraft in aviation increases. Besides the use of micro drone systems, the transport of larger freight volumes receives more and more attention. The UFO – Phase 1 project is dedicated to this kind of freight transport. Three exemplary scenarios covering a broad range of research questions have been selected for further investigation within the project.

1. INTRODUCTION

The idea of freight transport with remotely piloted aircraft systems (RPAS) led to the initiation of the two "Unmanned Freight Operations" (UFO) projects within DLR. Phase 0 as pilot phase evaluated the state of the art, assessed possible demand, and identified academic voids with respect to the operation of unmanned aircraft systems in German and European civil air space. The results have been the basis for the successor project "Unmanned Freight Operations – Phase 1" launched in November 2014 and planned until fall 2017. The projects are led by DLR's Institute of Flight Guidance.
Based on [1], EASA presented in May 2015 an approach to operate UAS of three different categories [2]. UFO – Phase 1 is mainly dedicated to the "certified" category. Here, it is assumed that unmanned aircraft run through a certification procedure equivalent to today's certification for manned aircraft. Nevertheless, before unmanned aircraft can be operated in the airspace and at airports, regulative and technical barriers have to be overcome. The objective of the DLR institutes involved in UFO – Phase 1 is the development and validation of a concept to operate unmanned freight aircraft. The project addresses operational concepts, questions with respect to certification procedures and necessary reliabilities, integration issues into the air traffic management system as well as requirements and limitations of communication data links.
Besides the Institute of Flight Guidance, four additional DLR facilities are involved in UFO – Phase 1.
To develop operational concepts for efficient airspace integration is one key aspect for the Institute of Flight Guidance. These concepts are based on three example use cases described in the next section Thereby, the integration of RPAS into current and future airspace structures, airside integration at airfields and aerodromes as well as solutions for controller systems and requirements regarding ground control stations are addressed. The deviation of technological as well as operational requirements and a respective concept lead to additional constraints regarding air traffic management procedures. This part of the project is led by DLR's Air Transportation department. DLR's Institute of Communications and Navigation develops Communications, Navigation, and Surveillance (CNS) concepts for RPAS operations. Aspects of flight control systems are the main part of DLR's Institute of Flight Systems within this project. Requirements regarding a remote pilot of UAS as well as human performance assessment processes are contributions of DLR's Institute of Aerospace Medicine.
Within the validation work package led by DLR's Institute of Flight Guidance, these concepts will be consolidated and assessed with respect to selected aspects in suitable simulation environments.

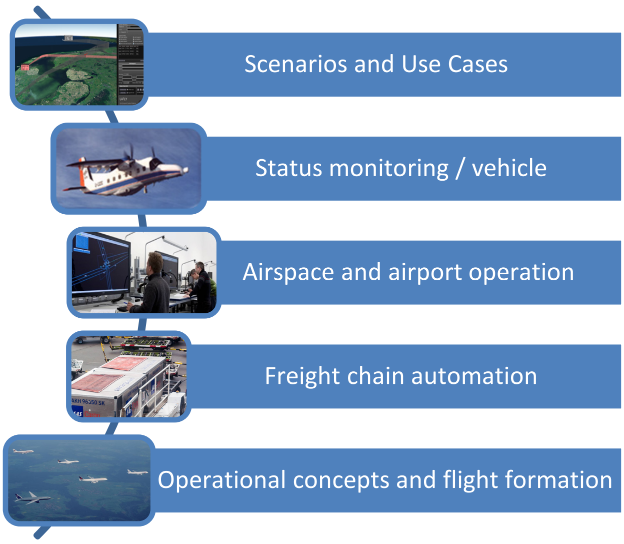

FIGURE 1. Overview UFO – Phase 1

In the following, an overview of the UFO – Phase 1 project is given. The aspects addressed within the project are shown in figure 1. In section 2 the three chosen example use cases and the RPAS specific research topics addressed with each use case are presented. A brief overview of the conceptual air traffic management (ATM) integration work related to these research questions with examples from the airside and airport integration is given in section 3. The validation exercises planned within the project are introduced in section 4.

2. EXAMPLE USE CASES

Before describing the selected example use cases for further studies within UFO – Phase 1, let us give a short overview about European and previous DLR activities with respect to use cases of unmanned air traffic.

SESAR JU has launched in 2012 a specific study on the integration of UAS in non-segregated airspace in a SESAR air traffic management scenario. The study, known as ICONUS (Initial CONOPS for UAS in SESAR) has been carried out by the ATM FUSION Consortium of Associate Partners to the SJU, see [3]. An overview of the study can be found in the UFO Phase 0 document [4] .
Within this study, the non-military applications of RPAS have been divided into three types:

- Commercial applications, such as aerial photography, surveying, patrol, agricultural application, cargo, will be performed for compensation or hire.
- Government (or public) applications, such as homeland security, weather observation, border surveillance, will be performed by or on behalf of federal states or governments.
- Non-Government – Non-commercial (or private) applications will include flights for personal use.

Overall, the ICONUS report covers ten possible use cases / stages of development in order to allow a safe integration of RPAS in civil ATM operations, where cargo transport is one of the commercial applications.
Within the unmanned freight operations projects, different unmanned cargo transport scenarios have been addressed and grouped with respect to the distance covered: Long distance, medium distance freight operations as well as intra-urban and local transport of goods. Possible use cases are manifold: organ and drug transport, food delivery, private-to-private direct transport as well as express parcel delivery and transport within large factory premises are associated with shorter distances. Delivery of urgent spare parts, humanitarian logistics, regular transport between production facilities and firefighting belong to the medium distance operations. The list is complemented by long distance operations like scheduled operation of freight transport and charter freight operations as point-to-point connection. Since the main focus of UFO – Phase 1 is the ATM integration of RPAS, mainly long and medium distance freight transports are covered within this project.
Based on the scenario descriptions and aspects relevant for these scenarios, the aim was to describe and select a set of example use cases that are able to cover together the main aspects of the integration of unmanned freight transport into the air traffic management system. These example use cases are then further elaborated and (partly) validated within the project.

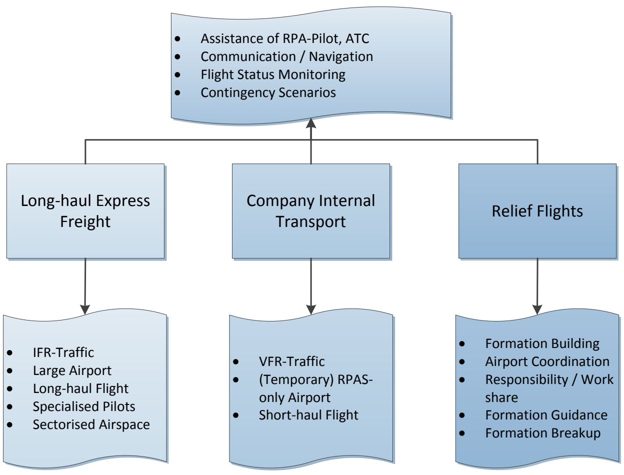

FIGURE 2. Overview of exemplary use cases

So the focus within the project evolved towards research questions that a number of scenarios have in common. After the identification of research questions, three exemplary use cases have been determined that cover together a broad range of the identified research questions. The three selected use cases are: Long-haul freight transport, flights on own account, and formation relief flights.
These are illustrated in figure 2 together with the focus of each use case. The following sections describe the exemplary use cases selected to determine constraints for further investigations within the UFO – Phase 1 project.

2.1. Long-Haul Express Freight

Although the economic feasibility of unmanned long distance freight transport irrespective of the choice of aircraft (modified manned freighter or new development) is unclear, such a use case requires the solution of challenging aspects related to a broader range of scenarios. Within this project, the aim of this use case is to validate how unmanned freight aircraft can be integrated in different phases of air transport and how humans can be assisted in their specific tasks. Thereby, focus will be given to different flight phases and different assumptions. The main idea is to use a common traffic scenario to analyse impact and conceptual integration ideas for RPAS on an airport specialized on RPAS traffic, on an en-route sector with unmanned and manned traffic under instrument flight rules (IFR), and on an airport with mixed traffic and not specifically equipped for frequent RPAS traffic. These sub-scenarios shall each be modelled in suitable (cooperating) simulation environments. Possible sub-scenarios cover e.g.:

- Impact on airports specialized on RPAS or with manned and unmanned mixed traffic
- Impact of different approach / departure procedures on conventional traffic, controllers, RPAS pilots, capacity
- Impact of different en-route procedures on conventional traffic controllers, RPAS pilots

For the purpose of these scenarios, we assume that current large freight aircraft - e.g. Boing 777F - are converted to allow unmanned operations. One of the first validation exercises is dedicated to this use case: The impact of using a sectorless approach to guide RPAS en-route, where conventional traffic is controlled in a sectored environment.

2.2. Company internal transport

This use case is an example for a transport task over a short distance under visual flight rules (VFR). Here, company-internal transport of goods or components from one factory location to another on a regular or irregular basis has been chosen as use case. The focus of this use case is the operation of unmanned freight aircraft at uncontrolled aerodromes. Thereby, we distinguish between aerodromes that are (temporarily) used exclusively by RPAS and common VFR aerodromes. Here, the integration of RPAS into VFR-traffic and the impact of and on other VFR-traffic can be analysed and compared to RPAS-only traffic. Although this use case would be possible in a similar way with an aircraft capable of vertical take-off and landing (VTOL), the use of a small aircraft that requires conventional take-off and landing (CTOL) is assumed. A CTOL has the advantage that questions related to manned and unmanned mixed VFR traffic as well as arrival and departure specific questions related to RPAS – e.g. runway capacity restrictions – can be addressed more easily within this project.

2.3. Relief Flights

The aim of this use case is to validate the possibilities of relief flights, using a Minimum Risk Configuration (MRC) as defined by EASA, see [2]. Single MRC flights are covered in the DLR project ALAADy (Automated Low Altitude Air DeliverY) [5], where the possibility of freight transport with a new aircraft type in low altitudes is addressed. The UFO use case relief flights focusses on formation flights, where a large amount of freight has to be transported with a couple of aircraft from one or a few airports to one destination. As use case, humanitarian logistics has been proposed. This use case has the aim to reduce the necessary effort and time for the delivery of relief items.
The idea in this case is to transport a larger amount of relief items with a group of aircraft to the place of disaster. Here, all flights will have the same destination airport and use a temporarily reserved corridor (as for military flights). In a first step also the departure airport will be the same for all flights. Questions resulting from different origins as e.g. intra-airport coordination are addressed in a second step. The freight is assumed to be goods for humanitarian aid. This use case addresses the possibility and restrictions to let one RPAS pilot be in charge of navigating a whole formation.

3. ATM INTEGRATION

Based on these scenarios, UFO – Phase 1 addresses the airspace integration, responsibility and distribution of tasks to actors, communication and navigation requirements in different flight phases, operation at different types of aerodromes, information needs of and propagation to actors, support of actors, functional requirements of aircraft and infrastructure and operational concepts regarding the logistics chain. Thereby, it will be assessed whether the developed concepts are also feasible in emergency situations, especially where challenges may result from the unmanned cockpit. Selected concepts are implemented and feasibility studies and validation exercises will be carried out in simulation environments. In this section, selected aspects and findings with respect to airspace and airport integration are presented. Tactical guidance is addressed in [6].

3.1. Airspace Integration

Within this project, concepts for the guidance of unmanned freight aircraft within controlled and uncontrolled airspace are elaborated. Current international roadmaps, see [1] and [7], are taken into account to address the foreseen RPAS integration into today's airspace system. In addition to the integration of RPAS within the existing airspace in due consideration of statutory requirements, standards, and ATM procedures new designs of airspace structures and new guidance concepts are included. Emergency procedures and aeronautical information management (AIM) are covered within the concepts as well. As one special aspect, the possibilities and constraints of RPAS formation flights are considered within the project.
With sectorless ATM, we exemplarily describe one concept for en-route air traffic management within this section: It envisions air traffic control without conventional sectors. Air traffic controllers will be assigned several aircraft regardless of their location. The controllers are responsible for their assigned flights from the entry into airspace to the exit. Such an aircraft-centered approach provides more flexibility, fewer handovers and enables user-preferred routes [8].
However, for RPAS integration, a complete introduction of sectorless ATM is not necessary. The airspace in general can e.g. still be managed in the conventional sectorized way. Only for RPAS sectorless ATM procedures and a dedicated RPAS controller could be introduced. This RPAS controller must be fully familiar with special properties and procedures of RPAS. Following the sectorless philosophy, this RPAS controller is responsible for all RPAS in the airspace, regardless of what sector they are in. All other aircraft are controlled as usual by the sectored controllers. The RPAS controller makes sure that the RPAS stay clear of surrounding traffic and give way in any conflicts. Although current roadmaps assume that RPAS are able to cope with current regulations, the sectorless concept for RPAS may reduce the necessary effort if RPAS with e.g. deviating flight performance are introduced.

3.2. Airport Integration

The examination of airside air-cargo aspects of RPAS operations is also part of the unmanned freight operations project. Ground handling operations, the involved stakeholders, the chronological order of operations and the overall ground traffic management are addressed.
Based on the analysis of manned cargo operations, new requirements and aerodrome processes designed for RPAS are derived. Besides this, some novel concepts for potential future RPAS operations at aerodromes are described and evaluated using various criteria within the project.
Within this paper we concentrate on surface movements. Thinking of the replacement of classic cargo operations by unmanned operations, there are several surface movement concepts that all have different constraints. In general, both segregated and non-segregated areas at aerodromes or even aerodromes dedicated alone to (part-time) RPAS use are conceivable for unmanned operations.
The following list gives an overview of parameters influencing the taxi process.

1) Mode of Driving
   a) Engines
   b) Wheel Tug
   c) TaxiBot
   d) Towing Vehicle (manual / automatic)
2) Trajectory Creation by
   a) Controller
   b) Automatic
   c) Standard Trajectories
3) Type of Movement
   a) Automatic
   b) Remote Pilot
   c) Third Person
4) Distribution of Traffic
   a) Segregated
   b) Non-Segregated

For this paper we have selected one approach, assuming non-segregated areas for RPAS operations. The modes of driving of the list above can be applied to manned and

unmanned aviation. An obvious alternative to a pilot on-board steering the aircraft on ground is the use of a towing vehicle. This is today often used to move an aircraft without a pilot between positons or to a maintenance hangar. If the use of towing vehicles shall be extended to move an RPA on the runway, some questions have to be taken into account, e.g. where the engines are started and where the towing vehicle does leave the aircraft.
Figure 2 illustrates this example for a ground movement concept with RPAS. Here, the towing vehicle is used for the whole surface movement until the aircraft reaches the line-up position on the runway. Before the line-up on the runway, the engines have to be started. To allow other aircraft to pass the RPA during engine start, an "engine-start-area" (ESA) can be placed in vicinity to the runway.

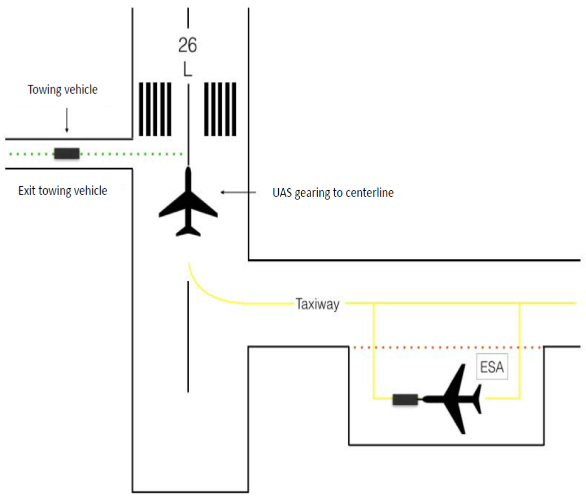

FIGURE 3. Aerodrome concept line-up with "Engine-Start-Area" (ESA) for RPA [9]

If the towing vehicle has hauled the RPA in line-up position, it has to be removed from the aircraft and the runway. In comparison to an aircraft moving by itself, additional time is necessary to remove the towing vehicle but the fuel consumption can be reduced allowing for more environmentally friendly operations. The impact on other movements depends on the traffic demand and is evaluated using fast time simulations within the UFO project.

4. VALIDATION EXERCISES

The validation exercises within this project are related to selected aspects of the example use cases illustrated in section 2. Validation is carried out in different simulation environments selected in accordance to the needs of the exercise. Available for the project are fast time simulation tools as e.g. AirTop [10] and real-time simulation environments. One of the first validation steps is the sectorless guidance concept depicted in section 3.1. This will be assessed with respect to feasibility and constraints on other air traffic participants. On the one-hand, a real-time environment will be used for the feasibility study and on the other a fast-time simulation is carried out to evaluate impact of adopted parameters – e.g. higher separation values – on airside capacity. A second validation exercise is a usability study from an ergonomic point of view of a ground control station developed within DLR. HMI elements for ATC assistance are under development and will be subject to a feasibility study in a second validation campaign. Fast-time simulation tools are in addition used to assess the impact of e.g. procedures like the aerodrome concept of section 3 or formation flights on airport or airspace capacity.

5. SUMMARY

This project deals with the increasing social interest in unmanned air freight transport. The validated concept demonstrates approaches that enable the future use of unmanned freight aircraft in addition to today's transport system. We have shown exemplarily two selected concepts addressing RPAS airspace integration on the one hand and airport integration on the other.

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